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PACKAGE CUSHIONING STANDARDIZATION STUDY.(U)
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PACKAGE CUSHIONING STANDARDIZATION STUDY

HQ AFALD/PTP
AIR FORCE PACKAGING EVALUATION AGENCY
Wright-Patterson AFB, OH 45433

November 1976

NOTICE

ABSTRACT

The objective of this study was to identify package cushioning materials which would provide the required levels of protection throughout the widest possible static stress ranges at the least possible cost.

The Package Design Program contained in the AFLC CREATE computer system was utilized to determine the most cost effective cushioning materials for two different methods of cushioning; complete encapsulation and corner pad design.

The complete encapsulation method of cushioning revealed that polyurethane, ether type, 2 lb/ft^3 density, was the most cost effective in the fragility levels of 30 to 50 Gs. The corner pad method of cushioning indicated that polystyrene foam, 1.5 lb/ft^3 density, was the most cost effective for the same fragility levels for items weighing from 25 to 200 lbs.

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INTRODUCTION

The manager of a packaging operation is faced with a myriad of decisions about package cushioning materials. He is concerned with the types of materials commercially available, quantity required, storage space available, and cost of the material. Because of the complexity of the considerations involved in material selection, the Air Force Packaging Evaluation Agency (AFPEA) has undertaken studies to simplify the packaging manager's decision-making efforts.

This study was initiated to provide the packaging operations manager with a select list of cushioning materials that will protect the widest variety of items at the lowest cost. The information in this report should be useful to Air Logistics Centers, Major Commands, and even to base level activities.

OBJECTIVE

The objective of this study was to identify cushioning materials which provide required levels of shock protection throughout the widest possible static stress range at the least possible cost.

ANALYSIS

Two steps were required to determine the most cost effective and versatile cushioning materials:

1) Determination of the static stress range that will include most Air Force items and also the distribution of these items through the range.

2) Determination by means of a computerized package cushion design program of the most cost effective cushioning materials that will protect items in the required static stress range.

Static Stress Range Determination. To determine an appropriate static stress range for use in this study, i.e., a range that could be expected to include most of the items in the Air Force inventory, a survey of transportation packaging orders (TPO) was made. Seventy TPOs were selected at random from the AFPEA master file. Three static stress values were calculated for each of the three pairs of opposite faces for each item. This resulted in a total of 210 static stress

points. These data were presented in the form of a bar graph (see graph 1). The points that fell within specific narrow static stress ranges were converted to percentages for later use in a "weighted" cost analysis.

Cost Considerations. To select the most cost effective and versatile cushioning materials, the total cost of a pack design must be considered. The dimensions, weight, and fragility of the item determines the amount and consequently the cost of the cushioning protection from a specific drop height. The size and cost of the container depends on item size and amount of cushioning material used. Labor costs are included for cutting and installing materials. Generally, transportation charges should also be considered when selecting a cushioning material; however, because they will vary considerably with the distance traveled, the mode of transport, and item weight, it was decided to exclude them for this analysis. This was done so that the difference in the total pack costs, using various cushioning materials, would be more apparent and not obscured by other variable factors.

Test Item (Mathematical Model). The size of the test item used for all cost comparisons was 12" x 12" x 12". The item was considered to be protected to various fragility levels for a drop height of 30". The weight of the item and its fragility were the only quantities varied.

Package Design Program. Two design options were used in the computerized Package Design Program to obtain cost data. One option was for the complete cushioning encapsulation and the other was for corner pad cushioning of an item.

Complete Encapsulation. Complete encapsulation is one of the most commonly used methods of protecting an item. The cushion pads are dimensional to fill all void spaces within the pack between the surface of the item and the inner surface of the shipping container.

The required input information to the computer is drop height, item dimensions, item weight, fragility, type of shipping container, container material, transportation mode and transportation distance. The program then outputs a list of materials that will protect the item and provides the total cost of the pack including transportation charges if desired. As was mentioned earlier, the transportation costs were not used for this analysis. After selecting the most cost effective cushioning materials identified for this particular input, a new set of data inputs (i.e., different item weights and/or fragilities) were used.

The most cost effective materials that will protect items over the widest static stress ranges at a given fragility level are listed in Table I.

Corner Pads. The other option used in the computer program to obtain cost data was corner pad cushioning. This method of cushioning utilizes a reduced area technique. The cushioning material is formed into corner pads which are applied to each of the corners of an intermediate (interior) container which holds the item. The intermediate container with corner pads is positioned within an outer shipping case. The bearing area of the corner pads is adjusted to utilize the optimum static stress design point for the cushioning material involved. The corner pad design requires a lesser amount of material than the complete encapsulation method and, therefore, usually results in material cost savings.

The same computer input data are required as for the complete encapsulation option. The program output is a list of materials in order of cost effectiveness which will protect the item, the total pack cost, and the dimensions of the corner pads to be used. Table II shows the three most cost effective cushioning materials and pack cost for each item weight with a range of fragilities from 15 to 50 Gs. Table III shows more readily the ranking of the five most cost effective materials without showing pack costs.

Cost Analysis (Complete Encapsulation). Two item stress (psi) distributions were considered in the cost analysis: 1) a uniform distribution of items throughout the required static stress range; 2) a "weighted" distribution of items throughout the required static stress range based on the distribution illustrated in graph 1.

Uniform Static Stress Distribution. In the cost analysis based on uniform static stress distribution, an equal number of packs were assumed at each static stress design point. For protection at a specific fragility level the relative pack costs for different types of cushioning materials were then determined by averaging the costs of the packs at each static stress value for a given material. For example, referring to material code No. 2, Table I, at a fragility level of 50 G, the total pack cost is given at each of seven static stress points. The average of these pack costs is provided in the last column of the Table. This average cost can be compared with the cost of other packs utilizing materials 4, 5, 3, and 6. In the second column of Table I, the materials are ranked in the order of descending cost effectiveness.

Note that at the 40 G fragility level the static stress points considered were reduced because the lowest stress range would not provide the required protection for all the materials considered. Examination of Table I reveals that below the fragility level of 25 G there are fewer materials capable of protecting the item.

Weighted Static Stress Distribution. It is believed that a more realistic cost analysis would be one based on the "weighted" static stress distribution presented in graph 1. Inspection of graph 1 indicates that approximately 94% of the TPOs evaluated are included in the static stress range of 0.04 to 0.5 psi. The materials considered in Table IV were limited to the three most cost effective materials identified for each fragility level in Table I. The average pack costs specified in Table IV for each static stress range and fragility level were "weighted" by multiplying the actual average pack cost for the indicated static stress range by the percentage value specified in graph 1 for the same static stress range. The weighted average pack cost for the total static stress range for a given fragility level was obtained by dividing the sum of the individual pack costs by the sum of the weighting factors.

Fewer packs are considered in the cost analysis at the lower fragility levels than at the higher levels because the static stress ranges over which the materials will provide the required protection are much narrower at the lower fragility levels. The static stress ranges used for the "weighted" distribution were the same as those used for the uniform distribution for a given fragility level. This allowed for a comparison of the average pack costs using both the "uniform" and "weighted" distribution analysis. For example, the total weighted average pack cost from Table IV for material No. 2 in the 50 G fragility level is $6.45 compared to $8.13 for the uniform distribution (Table I).

RESULTS

Complete Encapsulation. Both methods of cost analysis (uniform and weighted static stress distribution) for the complete encapsulation method of cushioning indicate that polyurethane, 2 lb/ft^3, ether (code no. 2), is the most economical and versatile material for protection in the 30 to 50 G fragility range (see Tables I & IV). The 1.5 and 2.0 lb/ft^3 ester type polyurethane materials are second and third, with respect to cost effectiveness. In the 15 to 25 G fragility range, very few materials will protect items, and the ones that do have very narrow static stress ranges (see

Table I). Polyurethane, 1.5 lb/ft^3, ether (code no. 1), is the most cost effective in the .04 to 0.1 psi static stress range and polyurethane, 2.0 lb/ft^3, ester (code no. 5), in the 0.1 to 0.5 psi static stress range.

To determine the effect of item size, if any, on the cost analysis using the same procedure as used for the uniform static stress distribution evaluation, a 6" x 6" x 6" item size was considered; the same material ranking was obtained as with the 12" x 12" x 12" item.

Corner Pads. Tables II and III indicate that for the corner pad method of cushioning, polystyrene foam, 1.5 lb/ft^3 (code no. 12), is the most economical material for item weights of 25 to 200 lbs with fragilities of 30 to 50 G. From 15 to 25 G fragility, polyurethane, 2.0 lb/ft^3, ester, (code no. 5), is the most cost effective material for lightweight items (25 lbs). Heavier items can only be protected to 20 to 25 G minimum.

CONCLUSIONS

Polyurethanes (1.5 and 2.0 lb/ft^3 ether and 2.0 lb/ft^3 ester) are the most cost effective cushioning materials over the widest required static stress range for the required G levels of protection using the complete encapsulation method of cushioning.

Polystyrene foam, 1.5 lb/ft^3, is the most cost effective material using the corner pad method of cushioning.

RECOMMENDATIONS

Since most cushioning requirements can be met with the following materials, it is recommended that the ALCs stock these cushioning materials as "standard" inventory:

1) Polyurethane, ether type, 1.5 and 2.0 lb/ft^3.

2) Polyurethane, ester type, 2.0 lb/ft^3.

3) Polystyrene foam, 1.5 lb/ft^3.

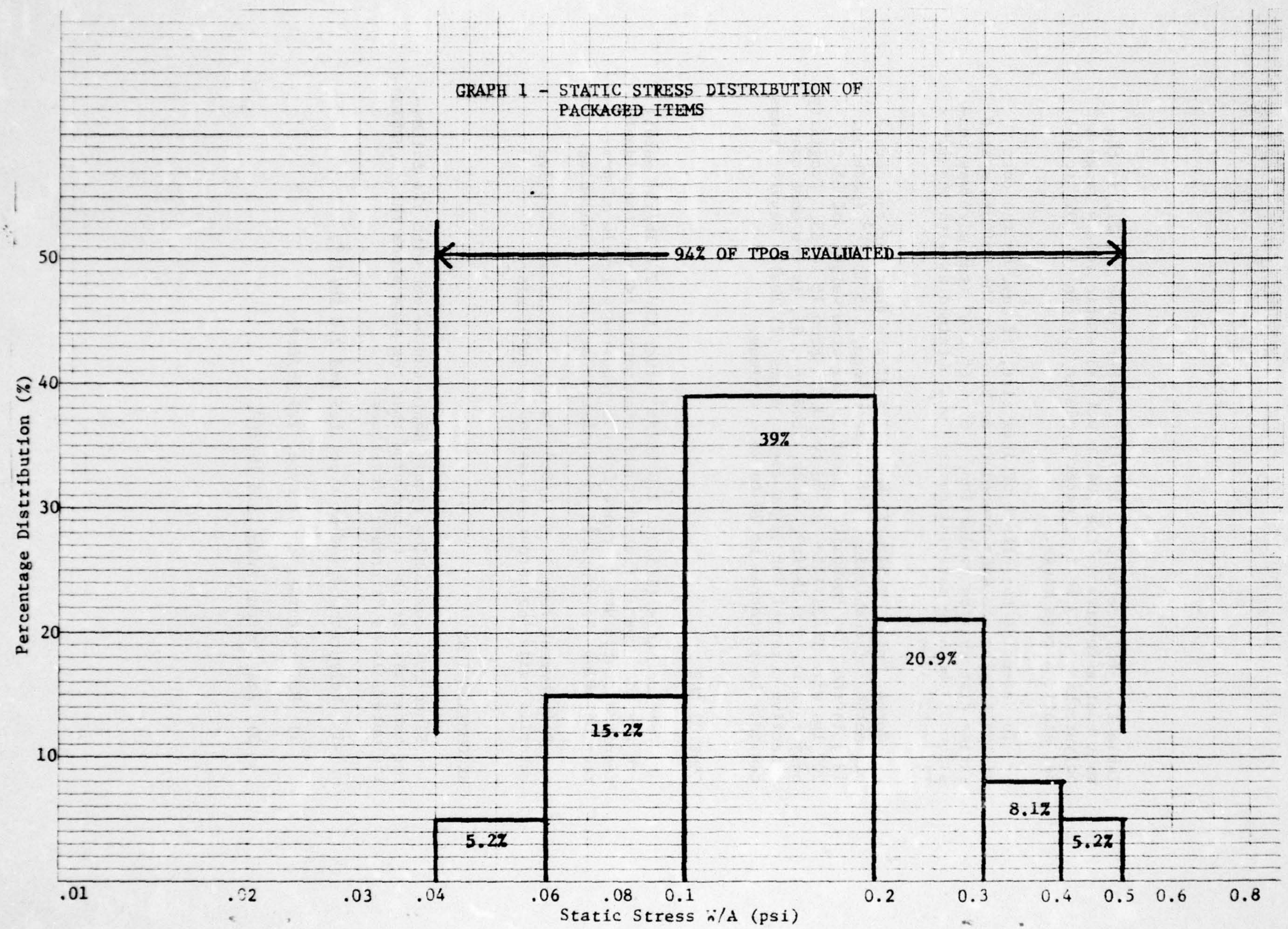
GRAPH 1 - STATIC STRESS DISTRIBUTION OF
PACKAGED ITEMS
94% OF TPOs EVALUATED
Percentage Distribution (%)
50
40
30
20
10
39%
20.9%
15.2%
8.1%
5.2%
5.2%
.01
.02
.03
.04
.06
.08
0.1
0.2
0.3
0.4
0.5
0.6
0.8
Static Stress W/A (psi)

TABLE I

COMPLETE ENCAPSULATION PACK DESIGN COSTS (UNIFORM STATIC STRESS DISTRIBUTION)

Fragility (Gs)	Ranked By Cost Effectiveness	Static Stress W/A (psi) and Item Weight: 5.76 lbs 0.04 psi	8.64 lbs 0.06 psi	14.4 lbs 0.10 psi	28.8 lbs 0.20 psi	43.2 lbs 0.30 psi	57.6 lbs 0.40 psi	72.0 lbs 0.50 psi	Average Pack Cost for Static Stress Ranges of:
									0.04 - 0.5 psi
	* 2	$ 5.03	$ 3.86	$ 5.03	$ 5.03	$ 9.42	$13.18	$15.33	$8.13
	4	12.85	10.94	7.63	7.63	7.63	7.63	7.63	8.85
50	5	21.44	15.90	5.88	5.88	7.49	7.49	9.28	10.48
	3	8.48	8.48	8.48	8.48	13.78	16.90	20.35	12.13
	6	16.79	13.32	10.21	10.21	10.21	13.32	13.32	12.48
									0.06 - 0.5 psi
	2	5.03	5.03	5.03	7.80	11.21	15.33	20.21	$10.76
	4		14.94	10.94	9.20	9.20	10.94	10.94	11.03
40	5		24.58	9.28	7.49	9.28	9.28	11.28	11.86
	6	24.95	16.79	13.32	10.21	13.32	16.79	16.79	14.54
	3	10.98	10.98	8.48	10.98	16.90	20.35	28.32	16.00
									0.1 - 0.4 psi
	2	7.80	5.03	6.34	11.21	15.33	20.21		$13.27
30	5			21.44	9.28	11.28	13.48	15.90	13.87
	4			19.69	12.85	12.85	14.94	14.94	15.08
	6	46.71	34.86	16.79	16.79	16.79	20.66	24.95	17.76
	3		20.35	13.78	16.90	24.15	28.32	32.88	20.79
									0.06 - 0.2 psi
	1	4.98	6.05	7.24	13.22				$ 8.84
	2		7.80	7.80	11.21	20.21			8.94
25	6		46.71	29.68	16.79	24.95	29.68	34.86	31.06
									0.10 - 0.5 psi
	5			24.58	13.48	13.48	15.90	18.55	$17.20
	6			29.68	16.79	24.95	29.68	34.86	27.19
	1	9.97	7.24	7.24					
20	2		11.21	7.80	15.33				
	5				21.44	18.55	18.55		
	6			40.53	24.95	29.68	34.86	46.71	
	1		8.54	8.54					
	2			11.21					
15	3				37.83				
	5					24.58			
	6				34.86	46.71			

DROP HEIGHT - 30"

COMPLETE ENCAPSULATION

ITEM SIZE - 12"x12"x12"

*Material Code Numbers:

1. Polyurethane -ether, 1.5 lb/ft^3.
2. Polyurethane -ether, 2.0 lb/ft^3.
3. Polyurethane -ether, 4.0 lb/ft^3
4. Polyurethane -ester, 1.5 lb/ft^3.
5. Polyurethane -ester, 2.0 lb/ft^3.
6. Polyurethane -ester, 4.0 lb/ft^3.

TABLE II

CORNER PAD PACK DESIGN COSTS

ITEM SIZE - 12" x 12" x 12" DROP HEIGHT - 30"

Item Wt. (lbs)	FRAGILITIES 50 G *Mat.	50 G Cost	40 G Mat.	40 G Cost	30 G Mat.	30 G Cost	25 G Mat.	25 G Cost	20 G Mat.	20 G Cost	15 G Mat.	15 G Cost
25	12	$ 2.88	12	$ 3.74	12	$ 6.05	5	$ 9.58	5	$12.70	5	$17.93
	4	4.53	5	5.76	5	8.18	2	10.42	2	14.65	6	29.95
	2	4.77	4	6.44	4	8.74	4	11.18	1	15.01		
50	12	3.32	12	4.31	12	6.86	5	14.38	5	18.20		
	13	5.86	13	8.20	5	11.42	4	14.55	6	31.12		
	4	6.37	5	8.29	4	11.51	10	21.37				
70	12	3.65	12	4.73	12	7.44	4	16.93	6	45.53		
	13	6.56	13	9.16	4	13.71	5	17.31				
	4	7.37	4	10.02	5	15.23	11	24.44				
100	12	4.12	12	5.32	12	8.22	11	28.49				
	13	7.54	13	10.50	4	17.18	10	29.52				
	4	9.27	4	12.60	10	20.12	14	32.96				
150	12	4.87	12	6.23	12	9.42	11	34.70				
	13	9.07	13	12.56	11	25.43	10	35.49				
	11	12.17	10	16.56	10	26.22	14	40.27				
200	12	6.10	12	8.13	12	10.54	11	40.50				
	13	10.52	13	14.51	11	29.95	14	47.09				
	11	14.45	10	19.75	10	32.65						

*Materials ranked by cost effectiveness in descending order. See Table III for Material Code Identification.

TABLE III

CORNER PAD PACK - *MOST COST EFFECTIVE MATERIALS

ITEM SIZE - 12" x 12" x 12"   DROP HEIGHT - 30"

FRAGILITIES

	50 Gs					40 Gs					30 Gs					25 Gs					20 Gs					15 Gs				
Ranking By Cost Effectiveness	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Item Wt. (lbs)																														
25	12	4	2	5	13	12	5	4	13	2	12	5	4	9	2	5	2	4	1	6	5	2	1	6	3	5	6			
50	12	13	4	10	11	12	13	5	4	10	12	5	4	10	11	5	4	10	11	14	5	6								
70	12	13	4	11	10	12	13	4	10	5	12	4	5	10	11	4	5	11	10	14	6									
100	12	13	4	11	10	12	13	4	10	11	12	4	10	11	5	11	10	14												
150	12	13	11	10	14	12	13	10	4	11	12	11	10	14		11	10	14												
200	12	13	11	14	10	12	13	10	11	14	12	11	10	14		11	14													

*1. Polyurethane - ether - 1.5 lb/ft^3
2. Polyurethane - ether - 2.0 lb/ft^3
3. Polyurethane - ether - 4.0 lb/ft^3
4. Polyurethane - ester - 1.5 lb/ft^3
5. Polyurethane - ester - 2.0 lb/ft^3
6. Polyurethane - ester - 4.0 lb/ft^3
9. Rubberized Hair - Type IV - 2.0 lb/ft^3
10. Polyethylene Foam - 2.0 lb/ft^3
11. Polyethylene Foam - 4.0 lb/ft^3
12. Polystyrene Foam - 1.5 lb/ft^3
13. Polystyrene Foam - 2.5 lb/ft^3
14. Polyethylene Minicell - L200 - 2.0 lb/ft^3

TABLE IV

COMPLETE ENCAPSULATION PACK DESIGN COSTS (WEIGHTED STATIC STRESS DISTRIBUTION)

Fragility (G)	Static Stress Range (psi)	*Material No. 2 Weighted Avg. Pack Cost ($)	Material No. 4 Weighted Avg. Pack Cost ($)	Material No. 5 Weighted Avg. Pack Cost ($)	Material No. 1 Weighted Avg. Pack Cost ($)	Material No. 6 Weighted Avg. Pack Cost ($)
	0.04 - 0.06	0.231	0.618	0.971		
	0.06 - 0.10	0.676	1.411	1.655		
50	0.10 - 0.20	1.962	2.976	2.293		
	0.20 - 0.30	1.510	1.595	1.397		
	0.30 - 0.40	0.915	0.618	0.607		
	0.40 - 0.50	0.741	0.397	0.436		
Total Range	0.04 - 0.50	$6.45	$8.13	$7.86		
	0.06 - 0.10	0.764	1.966	2.573		
	0.10 - 0.20	2.502	3.927	3.270		
40	0.20 - 0.30	1.986	1.923	1.752		
	0.30 - 0.40	1.075	0.815	0.752		
	0.40 - 0.50	0.924	0.569	0.534		
Total Range	0.06 - 0.50	$8.20	$10.41	$10.05		
	0.10 - 0.20	3.422	6.345	5.990		
30	0.20 - 0.30	2.773	2.685	2.148		
	0.30 - 0.40	1.439	1.125	1.003		
Total Range	0.10 - 0.40	$11.23	$14.93	$13.44		
25	0.06 - 0.10	1.185			1.010	5.805
	0.10 - 0.20	3.707			3.989	9.061
Total Range	0.06 - 0.20	$9.03			$9.22	$27.43
	0.10 - 0.20			7.421		9.061
25	0.20 - 0.30			2.817		4.362
	0.30 - 0.40			1.189		2.212
	0.40 - 0.50			0.895		1.678
Total Range	0.10 - 0.50			$16.83		$23.65

*See Table I for Material Code No.s

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Standard Cushioning
Cushioning Characteristics

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The objective of this study was to identify package cushioning materials which would provide the required levels of protection throughout the widest possible static stress ranges at the least possible cost.

The Package Design Program contained in the AFLC CREATE computer system was utilized to determine the most cost effective cushioning materials for two different methods of cushioning, complete encapsulation, and corner pad design. →
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ITEM 20. (cont fr p 1473A)

The complete encapsulation method of cushioning revealed that polyurethane, 2 lb/ft^3 density, was the most cost effective in the fragility levels of 30 to 50 Gs. The corner pad method of cushioning indicated that polystyrene foam, 1.5 lb/ft^3 density, was the most cost effective for the same fragility levels for items weighing from 25 to 200 lbs.

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